SEMICONDUCTOR LIGHT EMITTING DEVICES INCLUDING FLEXIBLE FILM HAVING THEREIN AN OPTICAL ELEMENT, AND METHODS OF ASSEMBLING SAME

Field of the Invention

This invention relates to semiconductor light emitting devices and fabricating methods therefor, and more particularly to packaging and packaging methods for semiconductor light emitting devices.

Background of the Invention

Semiconductor light emitting devices, such as Light Emitting Diodes (LEDs) or laser diodes, are widely used for many applications. As is well known to those having skill in the art, a semiconductor light emitting device includes a semiconductor light emitting element having one or more semiconductor layers that are configured to emit coherent and/or incoherent light upon energization thereof. It is also known that the semiconductor light emitting element generally is packaged to provide external electrical connections, heat sinking, lenses or waveguides, environmental protection and/or other functions for the semiconductor light emitting device. Packaging may be provided, at least in part, by at least partially surrounding the semiconductor light emitting device with a dome-shaped transparent plastic shell.

For example, it is known to provide a two-piece package for a semiconductor light emitting device wherein the semiconductor light emitting element is mounted on a substrate of, for example, alumina, aluminum nitride and/or other materials, which include electrical traces thereon, to provide external connections for the semiconductor light emitting element. A second substrate, which, for example, may be silver plated copper, is mounted on the first substrate, for example using glue, surrounding the semiconductor light emitting element. A lens may be placed on the second substrate over the semiconductor light emitting element. Light emitting diodes with two-piece packages as described above are described in Application Serial No. 10/446,532 to Loh, entitled *Power Surface Mount Light Emitting Die Package*, filed May 27, 2003, assigned to the assignee of the present invention, the

disclosure of which is hereby incorporated herein by reference in its entirety as if set forth fully herein.

It is often desirable to incorporate phosphor into a semiconductor light emitting device, to enhance the emitted radiation in a particular frequency band and/or to convert at least some of the radiation to another frequency band. Phosphors may be included in a semiconductor light emitting device using many conventional techniques. In one technique, phosphor is coated inside and/or outside the plastic shell. In other techniques, phosphor is coated on the semiconductor light emitting device itself, for example using electrophoretic deposition. In still other techniques, a drop of a material such as epoxy that contains phosphor therein may be placed inside the plastic shell, on the semiconductor light emitting device and/or between the device and the shell. This technique may be referred to as a "glob top". The phosphor coatings may also incorporate an index matching material and/or a separate index matching material may be provided. LEDs that employ phosphor coatings are described, for example, in U.S. Patents, 6,252,254; 6,069,440; 5,858,278; 5,813,753; 5,277,840; and 5,959,316.

Unfortunately, the packaging for a semiconductor light emitting device may be costly and, in some cases, more costly than the semiconductor light emitting element itself. Moreover, the assembly process also may be costly, time consuming and/or subject to failures.

Summary of the Invention

Some embodiments of the present invention provide semiconductor light emitting devices that include a substrate having a face, a flexible film that includes therein an optical element, on the face, and a semiconductor light emitting element between the substrate and the flexible film and configured to emit light through the optical element. In some embodiments, an optical coupling media, such as optical gel, is provided between the optical element and the semiconductor light emitting element. In some embodiments, the face includes a cavity therein, and the semiconductor light emitting element is in the cavity. The flexible film extends onto the face beyond the cavity, and the optical element overlies the cavity. In some embodiments, an optical coupling media is provided in the cavity. Semiconductor light emitting devices may be assembled, according to various embodiments of the present invention, by mounting a semiconductor light emitting element on a substrate

face, and attaching a flexible film that includes therein an optical element to the substrate face such that, in operation, the semiconductor light emitting element emits lights through the optical element. An optical coupling media may be placed between the semiconductor light emitting element and the optical coupling element.

Many different configurations of optical elements may be provided according to various embodiments of the present invention. In some embodiments, the optical element includes (i.e., comprises) a lens. In other embodiments, the optical element includes a prism. In other embodiments, the flexible film includes a first face adjacent the substrate and a second face remote from the substrate, and the optical element includes a first optical element on the first face, and a second optical element on the second face, both of which are located such that the light emitting element emits light through the first optical element and the second optical element. In some embodiments, the optical element includes phosphor and/or other optical emission enhancing and/or converting elements. In still other embodiments, the optical element includes an optical scattering element. Combinations and subcombinations of these and/or other optical elements also may be provided. Moreover, an optical coupling media may be provided between the optical element and the semiconductor light emitting element in any of these embodiments.

Many configurations of the flexible film also may be provided according to various embodiments of the present invention. For example, in some embodiments, at least a portion of the flexible film that overlies the cavity is transparent to the light, and at least a portion of the flexible film that extends onto the face beyond the cavity is opaque to the light. In other embodiments, at least a portion of the flexible film that overlies the cavity includes a first material and at least a portion of the flexible film that extends onto the face beyond the cavity includes a second material. In still other embodiments, the semiconductor light emitting element includes a wire that extends towards and contacts the flexible film in the cavity, and the flexible film includes a transparent conductor in the cavity that electrically connects to the wire. Combinations and subcombinations of these and/or other configurations of flexible film also may be provided.

In other embodiments, an attachment element also is provided that is configured to attach the flexible film and the substrate to one another. Many conventional attachment techniques can be used to provide an attachment element.

Some embodiments of the present invention may be configured to incorporate phosphor into the semiconductor light emitting device. In some embodiments, phosphor is provided on the flexible film between the lens and the semiconductor light emitting element. In other embodiments, the lens includes a concave inner surface adjacent the semiconductor light emitting element, and the phosphor includes a conformal phosphor layer on the concave inner surface. In yet other embodiments, the optical element includes a lens that overlies the cavity and protrudes away from the cavity, the flexible film further includes a protruding element between the lens and the light emitting element that protrudes towards the cavity, and a conformal phosphor coating is provided on the protruding element. Combinations and subcombinations of these and/or other configurations of phosphor also may be provided. Moreover, an optical coupling media may be provided between the phosphor and the semiconductor light emitting element in any of these embodiments.

In still other embodiments of the present invention, the semiconductor light emitting element includes a wire that extends towards the flexible substrate. In some of these embodiments, the optical element includes a prism that is configured to reduce shadowing by the wire, of the light that is emitted from the semiconductor light emitting element.

Multiple semiconductor light emitting elements and/or optical elements may be incorporated in a semiconductor light emitting device according to various embodiments of the present invention. Each semiconductor light emitting element may be included in its own individual cavity and/or multiple semiconductor light emitting elements may be included in a single cavity. Moreover, in some embodiments, the same phosphor may be included on the flexible film for each optical element. In other embodiments, different phosphors may be used. For example, a first phosphor layer and a first semiconductor light emitting element may be configured to generate red light, a second phosphor layer and a second semiconductor light emitting element may be configured to generate blue light, and a third phosphor layer and a third semiconductor light emitting element may be configured to generate green light. Combinations and subcombinations of these and/or other multiple semiconductor light emitting elements and/or multiple optical elements also may be provided. Finally, combinations and subcombinations of these and/or other optical elements, flexible films, phosphor and/or multiple elements may be provided, according to various embodiments of the present invention.

Brief Description of the Drawings

Figure 1 is an exploded cross-sectional view of semiconductor light emitting devices and fabrication methods therefor, according to various embodiments of the present invention.

Figures 2-12 are cross-sectional views of semiconductor light emitting devices according to various embodiments of the present invention.

Figure 13 is a perspective view of a semiconductor light emitting device according to various embodiments of the present invention.

Detailed Description

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity. Like numbers refer to like elements throughout.

It will be understood that when an element such as a layer, region or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. It will be understood that if part of an element, such as a surface, is referred to as "inner," it is farther from the outside of the device than other parts of the element. Furthermore, relative terms such as "beneath" or "overlies" may be used herein to describe a relationship of one layer or region to another layer or region relative to a substrate or base layer as illustrated in the figures. It will be understood that these terms are intended to encompass different orientations of the device in addition to the orientation depicted in the figures. Finally, the term "directly" means that there are no intervening elements. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these

terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first region, layer or section discussed below could be termed a second region, layer or section, and, similarly, a second without departing from the teachings of the present invention.

Figure 1 is an exploded cross-sectional view of semiconductor light emitting devices and assembling methods therefor, according to various embodiments of the present invention. Referring to Figure 1, these semiconductor light emitting devices **100** include a substrate **110** having a face **110a**, a flexible film **120** that includes therein an optical element **130**, on the face **110a**, and a semiconductor light emitting element **140** between the substrate **110** and the flexible film **120**, and configured to emit light **160** through the optical element. An attachment element **150** may be used to attach the flexible film **120** and the substrate **110** to one another.

Still referring to Figure 1, the substrate **110** may include alumina, aluminum nitride, metal and/or other materials that are conventionally used for mounting semiconductor light emitting elements thereon. In other embodiments, the substrate **110** can be a solid metal block, as described in copending Application Serial No. 10/659,108 to Negley et al., entitled *Solid Metal Block Mounting Substrates for Semiconductor Light Emitting Devices, and Oxidizing Methods for Fabricating Same*, filed September 9, 2003, assigned to the assignee of the present invention, the disclosure of which is hereby incorporated herein by reference in its entirety as if set forth fully herein. The design of substrates **110** are well known to those having skill in the art and need not be described further herein.

The semiconductor light emitting element **140** may include a light emitting diode, laser diode and/or other semiconductor device which includes one or more semiconductor layers, which may include silicon, silicon carbide, gallium nitride and/or other semiconductor materials, a substrate which may include sapphire, silicon, silicon carbide and/or other microelectronic substrates, and one or more contact layers which may include metal and/or other conductive layers. In some embodiments, ultraviolet, blue and/or green LEDs may be provided. The design and fabrication of semiconductor light emitting devices **140** are well known to those having skill in the art and need not be described in detail herein.

For example, the light emitting elements **140** may be gallium nitride-based LEDs or lasers fabricated on a silicon carbide substrate such as those devices manufactured and sold by Cree, Inc. of Durham, North Carolina. The present

invention may be suitable for use with LEDs and/or lasers as described in United States Patent Nos. 6,201,262; 6,187,606; 6,120,600; 5,912,477; 5,739,554; 5,631,190; 5,604,135; 5,523,589; 5,416,342; 5,393,993; 5,338,944; 5,210,051; 5,027,168; 5,027,168; 4,966,862 and/or 4,918,497, the disclosures of which are incorporated herein by reference as if set forth fully herein. Other suitable LEDs and/or lasers are described in published U.S. Patent Publication No. US 2003/0006418 A1 entitled *Group III Nitride Based Light Emitting Diode Structures With a Quantum Well and Superlattice, Group III Nitride Based Quantum Well Structures and Group III Nitride Based Superlattice Structures*, published January 9, 2003, as well as published U.S. Patent Publication No. US 2002/0123164 A1 entitled *Light Emitting Diodes Including Modifications for Light Extraction and Manufacturing Methods Therefor*. Furthermore, phosphor coated LEDs, such as those described in U.S. Application Serial No. 10/659,241, entitled *Phosphor-Coated Light Emitting Diodes Including Tapered Sidewalls and Fabrication Methods Therefor*, filed September 9, 2003, the disclosure of which is incorporated by reference herein as if set forth fully, may also be suitable for use in embodiments of the present invention. The LEDs and/or lasers may be configured to operate such that light emission occurs through the substrate. In such embodiments, the substrate may be patterned so as to enhance light output of the devices as is described, for example, in the above-cited U.S. Patent Publication No. US 2002/0123164 A1.

Still referring to Figure 1, the flexible film **120** can provide a cover slip that can be made of a flexible material such as a conventional Room Temperature Vulcanizing (RTV) silicone rubber. Other silicone-based and/or flexible materials may be used. By being made of a flexible material, the flexible film **120** can conform to the substrate **110** as it expands and contracts during operations. Moreover, the flexible film **120** can be made by simple low-cost techniques such as transfer molding, injection molding and/or other conventional techniques that are well known to those having skill in the art.

As described above, the flexible film **120** includes therein an optical element **130**. The optical element can include a lens, a prism, an optical emission enhancing and/or converting element, such as a phosphor, an optical scattering element and/or other optical element. One or more optical elements **130** also may be provided, as will be described in detail below. Moreover, as shown in Figure 1, an optical coupling media **170**, such as an optical coupling gel and/or other index matching

material, may be provided between the optical element **130** and the semiconductor light emitting device **140**, in some embodiments.

Still referring to Figure 1, the attachment element **150** can be embodied as an adhesive that may be placed around the periphery of the substrate **110**, around the periphery of the flexible film **120** and/or at selected portions thereof, such as at the corners thereof. In other embodiments, the substrate **110** may be coined around the flexible film **120**, to provide an attachment element **150**. Other conventional attaching techniques may be used.

Figure 1 also illustrates methods of assembling semiconductor light emitting devices **100** according to various embodiments of the present invention. As shown in Figure 1, a semiconductor light emitting element **140** is mounted on a substrate face **110a**. A flexible film **120** that includes therein an optical element **130** is attached to the substrate face **110a**, for example using an attachment element **150**, such that, in operation, the semiconductor light emitting element emits light **160** through the optical element **130**. In some embodiments, an optical coupling media **170** is placed between the semiconductor light emitting element **140** and the optical element **130**.

Figure 2 is a cross-sectional view of semiconductor light emitting devices according to other embodiments of the present invention. In these embodiments, the substrate face **110a** includes a cavity **110b** therein. The flexible film **120** extends onto the face **110a** beyond the cavity **110b**. The optical element **130** overlies the cavity **110b**, and the semiconductor light emitting element **140** is in the cavity **110b**, and is configured to emit light **160** through the optical element **130**. In Figure 2, the optical element **130** includes a concave lens. In some embodiments, an optical coupling media **170** is provided in the cavity **110b** between the optical element **130** and the semiconductor light emitting element **140**. In some embodiments, the optical coupling media **170** fills the cavity **110b**.

Figure 3 is a cross-sectional view of other embodiments of the present invention. As shown in Figure 3, two optical elements **130** and **330** are included in the flexible film **120**. A first optical element **130** includes a lens and a second optical element **330** includes a prism. Light from the semiconductor light emitting element **140** passes through the prism **330** and through the lens **130**. An optical coupling media **170** also may be provided. In some embodiments, the optical coupling media **170** fills the cavity **110b**. The optical coupling media **170** may have a sufficient difference in index of refraction difference from the prism such that the prism can

reduce shadowing. As shown in Figure 3, the semiconductor light emitting element includes a wire **140a** that extends towards the flexible film **120**, and the prism **330** is configured to reduce shadowing by the wire **140a** of the light that is emitted from the semiconductor light emitting element **140**. More uniform light emissions thereby may be provided, with reduced shadowing of the wire **140a**. It will be understood that the term "wire" is used herein in a generic sense to encompass any electrical connection for the semiconductor light emitting element **140**.

Figure 4 is a cross-sectional view of other embodiments of the present invention. As shown in Figure 4, phosphor **410** is provided on the flexible film **120** between the lens **130** and the semiconductor light emitting element **140**. The phosphor **410** can include cerium-doped Yttrium Aluminum Garnet (YAG) and/or other conventional phosphors. In some embodiments, the phosphor comprises Cesium doped Yttrium Aluminum Garnet (YAG:Ce). In other embodiments, nano-phosphors may be used. Phosphors are well known to those having skill in the art and need not be described further herein. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

Figure 5 illustrates yet other embodiments of the present invention. In these embodiments, the lens **130** includes a concave inner surface **130a** adjacent the semiconductor light emitting element **140**, and the phosphor **410** includes a conformal phosphor layer on the concave inner surface **130a**. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

Figure 6 is a cross-sectional view of other embodiments. As shown in Figure 6, at least a portion **120d** of the flexible film **120** that overlies the cavity **110b** is transparent to the light. Moreover, at least a portion **120c** of the flexible film **120** that extends onto the face **110a** beyond the cavity **110b** is opaque to the light, as shown by the dotted portions **120c** of the flexible film **120**. The opaque regions **120c** can reduce or prevent bouncing of light rays, and thereby potentially produce a more desirable light pattern. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

Figure 7 is a cross-sectional view of other embodiments of the present invention wherein the flexible film **120** may be fabricated of multiple materials. As shown in Figure 7, at least a portion **120d** of the flexible film **120** that overlies the cavity **110b** includes a first material, and at least a portion **120c** of the flexible film **120** that extends onto the face **110a** beyond the cavity **110b** includes a second

material. Two or more materials may be used in the flexible film **120** in some embodiments, to provide different characteristics for the portion of the flexible film **120** through which light is emitted and through which light is not emitted. Multiple materials may be used for other purposes in other embodiments. For example, an inflexible and/or flexible plastic lens may be attached to a flexible film. Such a flexible film **120** with multiple materials may be fabricated using conventional multiple molding techniques, for example. In some embodiments, the first material that is molded may not be fully cured, so as to provide a satisfactory bond that attaches to the second material that is subsequently molded. In other embodiments, the same material may be used for the optical element and the flexible film, wherein the optical element is formed and then the flexible film is formed surrounding the optical element. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

Figure 8 is a cross-sectional view of other embodiments of the present invention. In these embodiments, the semiconductor light emitting element **140** includes a wire **140a**, that extends towards and contacts the flexible film **120** in the cavity **110b**. The flexible film **120** includes a transparent conductor **810** which can include Indium Tin Oxide (ITO) and/or other conventional transparent conductors. The transparent conductor **810** extends in the cavity **110b** and electrically connects to the wire. Reduced shadowing by the contact **140a** thereby may be provided. Moreover, a wire bond to the substrate **110**, and the potential consequent light distortion, may be reduced or eliminated. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

Figure 9 is a cross-sectional view of other embodiments of the present invention. As shown in Figure 9, the optical element **130** includes a lens that overlies the cavity **110b** and protrudes away from the cavity **110b**. The flexible film **120** further includes a protruding element **930** between the lens **130** and the light emitting element **140** that protrudes towards the cavity **110b**. As shown in Figure 9, a conformal phosphor layer **410** is provided on the protruding element **930**. By providing the protruding element **930** on the back of the lens **130**, optical coupling media **170** in the device may be displaced. Arrangements of Figure 9 may thus provide more uniform phosphor coating at desired distances from the light emitting element **140**, so as to provide more uniform illumination. The optical coupling media **170** may fill the cavity **110b**.

Figures 10 and 11 illustrate semiconductor light emitting devices including multiple semiconductor light emitting elements and/or multiple optical elements according to various embodiments of the present invention. For example, as shown in Figure 10, the optical element **130** is a first optical element, and the semiconductor light emitting element **140** is a first semiconductor light emitting element. The flexible film **120** also includes therein a second optical element **130'** that is spaced apart from the first optical element **130**, and the device further includes a second semiconductor light emitting element **140'** between the substrate **110** and the flexible film **120**, and configured to emit light through the second optical element **130'**. Moreover, a third optical element **130"** and a third semiconductor light emitting element **140"** also may be provided. The optical elements **130**, **130'** and **130"** may be the same and/or different from one another, and the semiconductor light emitting elements **140**, **140'** and **140"** may be the same and/or different from one another. Moreover, in embodiments of Figure 10, the cavity **110b** is a first cavity, and second and third cavities **110b'**, **110b"**, respectively, are provided for the second and third semiconductor light emitting elements **140'**, **140"**, respectively. The cavities **110b**, **110b'** and **110b"** may be the same and/or may have different configurations from one another. An optical coupling media **170** also may be provided that may fill the cavity or cavities.

As also shown in Figure 10, the phosphor **410** may be a first phosphor layer, and second and/or third phosphor layers **410'** and **410"**, respectively, may be provided on the flexible film **120** between the second optical element **130'** and the second semiconductor light emitting element **140'**, and between the third optical element **130"** and the third semiconductor light emitting element **140"**, respectively. The phosphor layers **410**, **410'**, **410"** may be the same, may be different and/or may be eliminated. In particular, in some embodiments of the present invention, the first phosphor layer **410** and the first semiconductor light emitting element **140** are configured to generate red light, the second phosphor layer **410'** and the second semiconductor light emitting element **140'** are configured to generate blue light, and the third phosphor layer **410"** and the third semiconductor light emitting element **140"** are configured to generate green light. A Red, Green, Blue (RGB) light emitting element that can emit white light thereby may be provided in some embodiments.

Figure 11 is a cross-sectional view of other embodiments of the present invention. In these embodiments, a single cavity **1100** is provided for the first, second and third semiconductor light emitting elements **140**, **140'** and **140"**, respectively. An optical coupling media **170** also may be provided that may fill the cavity **1100**.

Figure 12 is a cross-sectional view of yet other embodiments of the present invention. In Figure 12, the optical element **1230** comprises a lens having phosphor dispersed therein. Lenses including phosphor dispersed therein are described, for example, in Application Serial No. 10/659,240 to Negley et al., entitled *Transmissive Optical Elements Including Transparent Plastic Shell Having a Phosphor Dispersed Therein, and Methods of Fabricating Same*, filed September 9, 2003, assigned to the assignee of the present invention, the disclosure of which is hereby incorporated herein by reference in its entirety as if set forth fully herein. An optical coupling media **170** also may be provided that may fill the cavity **110b**.

In still other embodiments of the present invention, an optical scattering element may be embedded in the lens as shown in Figure 12, and/or provided as a separating layer as shown, for example, in Figure 9, in addition or instead of phosphor.

Figure 13 is a perspective view of semiconductor light emitting devices according to other embodiments of the present invention. The substrate **110** is attached to a conventional package **1310**. An optical coupling media **170** also may be provided.

It will be understood by those having skill in the art that various embodiments of the invention have been described individually in connection with Figures 1-13. However, combinations and subcombinations of the embodiments of Figures 1-13 may be provided according to various embodiments of the present invention.

Additional discussion of various embodiments of the present invention now will be provided. In particular, in some embodiments, the flexible film **120** that was described above may be made of a flexible material such as RTV, GE RTV 615 marketed by GE, UR 234 marketed by Thermoset/Lord Corp. and/or other conventional flexible materials, and in some embodiment may be between about 25μm and about 500μm thick. The flexible film **120** incorporates one or more optical elements **130** to achieve a desired optical design. Being made of a flexible material, the flexible film **120** can conform to the semiconductor light emitting device as it expands and contracts. Moreover, in some embodiments, the flexible film can be

fabricated by simple low cost techniques such as transfer molding, injection molding and/or other techniques, and may include multiple optical elements and/or other features on either side of the flexible film membrane. This may permit a "single" placement of a complex optical element upon a package (or substrate to a package) that can include multiple LED emitters.

Conventionally, LED packages use a lens molded from rigid plastic or glass. Either a hard encapsulant is used to encapsulate the chip and form the optical element, or a lens is applied upon an optical coupling media, such as an optical gel, for example Nye optical gel. The hard encapsulant may be plagued by optical degradation and high stress on LED chips, and power LED chips in particular, and the optical coupling media may also potentially create problems because this gel may be exposed on the surface of the part which may result in trapping of dust/debris on the exposed material due to the stickiness of the gel. In contrast, flexible films **120** according to some embodiments of the present invention can be the terminating surface of the package using an optical coupling media **170**, and also includes the optical elements **130**, such as one or more optical lens. The ability to place one unit (the flexible film with multiple optical elements) can potentially provide a benefit when using a package that has multiple LEDs in it. Instead of placing a lens for each LED, the single placement of a flexible film **130** can be provided.

Still other features can be incorporated into the flexible film **130**. For example, on the opposing side of the optical lens, a filled region including a phosphor and/or an optical coupling media **170** may be incorporated to give the features of a paint-on lens for making white light. A paint-on lens for making white light is described in Application Serial No. 10/666,399 to Michael Leung, entitled *Molded Chip Fabrication Method and Apparatus*, filed September 18, 2003, assigned to the assignee of the present invention, the disclosure of which is hereby incorporated herein by reference in its entirety as if set forth fully herein.

Some embodiments of the present invention can reduce or minimize the volume of optical coupling media **170**, by providing a protrusion such as was described, for example, in Figure 9. By reducing the amount of optical coupling media **170**, a more uniform light emission may be provided. Thus, these and/or other embodiments of the present invention can reduce or eliminate angular-dependent radiation patterns of light output from the light emitting device, such as angular dependence of Color Correlated Temperature (CCT). Thus, light intensity and the x,

y chromaticity values/coordinates from all surfaces of the device can remain relatively constant in some embodiments. This may be advantageous when used for illumination applications, such as in a room, where a spotlight effect is not desirable.

In the drawings and specification, there have been disclosed embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.